

paragraphs (f)(3) before the table, and (l) introductory text, effective July 7, 2008. For the convenience of the user, the revised text is set forth as follows:

**§ 1065.602 Statistics.**

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(f) \* \* \*

(3) Use Table 1 of this section to compare  $t$  to the  $t_{crit}$  values tabulated versus the number of degrees of freedom. If  $t$  is less than  $t_{crit}$ , then  $t$  passes the  $t$ -test. The Microsoft Excel software package contains a TINV function that returns results equivalent to §1065.602 Table 1 and may be used in place of Table 1.

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(l) *Flow-weighted mean concentration.* In some sections of this part, you may need to calculate a flow-weighted mean concentration to determine the applicability of certain provisions. A flow-weighted mean is the mean of a quantity after it is weighted proportional to a corresponding flow rate. For example, if a gas concentration is measured continuously from the raw exhaust of an engine, its flow-weighted mean concentration is the sum of the products of each recorded concentration times its respective exhaust molar flow rate, divided by the sum of the recorded flow rate values. As another example, the bag concentration from a CVS system is the same as the flow-weighted mean concentration because the CVS system itself flow-weights the bag concentration. You might already expect a certain flow-weighted mean concentration of an emission at its standard based on previous testing with similar engines or testing with similar equipment and instruments. If you need to estimate your expected flow-weighted mean concentration of an emission at its standard, we recommend using the following examples as a guide for how to estimate the flow-weighted mean concentration expected at the standard. Note that these examples are not exact and that they contain assumptions that are not always valid. Use good engineering judgment to determine if you can use similar assumptions.

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**§ 1065.610 Duty cycle generation.**

This section describes how to generate duty cycles that are specific to your engine, based on the normalized duty cycles in the standard-setting part. During an emission test, use a duty cycle that is specific to your engine to command engine speed, torque, and power, as applicable, using an engine dynamometer and an engine operator demand. Paragraph (a) of this section describes how to “normalize” your engine’s map to determine the maximum test speed and torque for your engine. The rest of this section describes how to use these values to “denormalize” the duty cycles in the standard-setting parts, which are all published on a normalized basis. Thus, the term “normalized” in paragraph (a) of this section refers to different values than it does in the rest of the section.

(a) *Maximum test speed,  $f_{ntest}$ .* This section generally applies to duty cycles for variable-speed engines. For constant-speed engines subject to duty cycles that specify normalized speed commands, use the no-load governed speed as the measured  $f_{ntest}$ . This is the highest engine speed where an engine outputs zero torque. For variable-speed engines, determine the measured  $f_{ntest}$  from the power-versus-speed map, generated according to §1065.510, as follows:

(1) Based on the map, determine maximum power,  $P_{max}$ , and the speed at which maximum power occurred,  $f_{nPmax}$ . Divide every recorded power by  $P_{max}$  and divide every recorded speed by  $f_{nPmax}$ . The result is a normalized power-versus-speed map. Your measured  $f_{ntest}$  is the speed at which the sum of the squares of normalized speed and power is maximum, as follows:

$$f_{ntest} = f_{ni} \text{ at the maximum of } (f_{nnormi}^2 + P_{normi}^2) \quad \text{Eq. 1065.610-1}$$

Where:

$f_{ntest}$  = maximum test speed.

$i$  = an indexing variable that represents one recorded value of an engine map.

$f_{nnormi}$  = an engine speed normalized by dividing it by  $f_{nPmax}$ .

$P_{normi}$  = an engine power normalized by dividing it by  $P_{max}$ .

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## Example:

$(f_{\text{norm}1} = 1.002, P_{\text{norm}1} = 0.978, f_{n1} = 2359.71)$   
 $(f_{\text{norm}2} = 1.004, P_{\text{norm}2} = 0.977, f_{n2} = 2364.42)$   
 $(f_{\text{norm}3} = 1.006, P_{\text{norm}3} = 0.974, f_{n3} = 2369.13)$   
 $(f_{\text{norm}1}^2 + P_{\text{norm}1}^2) = (1.002^2 + 0.978^2) = 1.960$   
 $(f_{\text{norm}1}^2 + P_{\text{norm}1}^2) = (1.004^2 + 0.977^2) = 1.963$   
 $(f_{\text{norm}1}^2 + P_{\text{norm}1}^2) = (1.006^2 + 0.974^2) = 1.961$   
 maximum = 1.963 at  $i = 2$   
 $f_{\text{ntest}} = 2364.42 \text{ rev/min}$

(2) For variable-speed engines, transform normalized speeds to reference speeds according to paragraph (c) of this section by using the measured maximum test speed determined according to paragraph (a)(1) of this section—or use your declared maximum test speed, as allowed in § 1065.510.

(3) For constant-speed engines, transform normalized speeds to reference speeds according to paragraph (c) of

this section by using the measured no-load governed—speed or use your declared maximum test speed, as allowed in § 1065.510.

(b) *Maximum test torque,  $T_{\text{test}}$ .* For constant-speed engines, determine the measured  $T_{\text{test}}$  from the power-versus-speed map, generated according to § 1065.510, as follows:

(1) Based on the map, determine maximum power,  $P_{\text{max}}$ , and the speed at which maximum power occurs,  $f_{\text{nPmax}}$ . Divide every recorded power by  $P_{\text{max}}$  and divide every recorded speed by  $f_{\text{nPmax}}$ . The result is a normalized power-versus-speed map. Your measured  $T_{\text{test}}$  is the speed at which the sum of the squares of normalized speed and power is maximum, as follows:

$$T_{\text{test}} = T_i \text{ at the maximum of } (f_{\text{norm}i}^2 + P_{\text{norm}i}^2) \quad \text{Eq. 1065.610-2}$$

Where:

$T_{\text{test}}$  = maximum test torque.

## Example:

$(f_{\text{norm}1} = 1.002, P_{\text{norm}1} = 0.978, T_1 = 722.62 \text{ N} \cdot \text{m})$   
 $(f_{\text{norm}2} = 1.004, P_{\text{norm}2} = 0.977, T_2 = 720.44 \text{ N} \cdot \text{m})$   
 $(f_{\text{norm}3} = 1.006, P_{\text{norm}3} = 0.974, T_3 = 716.80 \text{ N} \cdot \text{m})$   
 $(f_{\text{norm}1}^2 + P_{\text{norm}1}^2) = (1.002^2 + 0.978^2) = 1.960$   
 $(f_{\text{norm}1}^2 + P_{\text{norm}1}^2) = (1.004^2 + 0.977^2) = 1.963$   
 $(f_{\text{norm}1}^2 + P_{\text{norm}1}^2) = (1.006^2 + 0.974^2) = 1.961$   
 maximum = 1.963 at  $i = 2$   
 $T_{\text{test}} = 720.44 \text{ Nm}$

(2) Transform normalized torques to reference torques according to paragraph (d) of this section by using the

measured maximum test torque determined according to paragraph (b)(1) of this section—or use your declared maximum test torque, as allowed in § 1065.510.

(c) *Generating reference speed values from normalized duty cycle speeds.* Transform normalized speed values to reference values as follows:

(1) *% speed.* If your normalized duty cycle specifies % speed values, use your declared warm idle speed and your maximum test speed to transform the duty cycle, as follows:

$$f_{\text{nref}} = \% \text{ speed} \cdot (f_{\text{ntest}} - f_{\text{nidle}}) + f_{\text{nidle}} \quad \text{Eq. 1065.610-3}$$

## Example:

$\% \text{ speed} = 85 \%$   
 $f_{\text{ntest}} = 2364 \text{ rev/min}$   
 $f_{\text{nidle}} = 650 \text{ rev/min}$   
 $f_{\text{nref}} = 85 \% \cdot (2364 - 650) + 650$   
 $f_{\text{nref}} = 2107 \text{ rev/min}$

(2) *A, B, and C speeds.* If your normalized duty cycle specifies speeds as A, B, or C values, use your power-versus-

speed curve to determine the lowest speed below maximum power at which 50 % of maximum power occurs. Denote this value as  $n_{lo}$ . Also determine the highest speed above maximum power at which 70 % of maximum power occurs. Denote this value as  $n_{hi}$ . Use  $n_{hi}$  and  $n_{lo}$  to calculate reference values for A, B, or C speeds as follows:

$$f_{\text{nrefA}} = 0.25 \cdot (n_{\text{hi}} - n_{\text{lo}}) + n_{\text{lo}} \quad \text{Eq. 1065.610-4}$$

$$f_{\text{nrefB}} = 0.50 \cdot (n_{\text{hi}} - n_{\text{lo}}) + n_{\text{lo}} \quad \text{Eq. 1065.610-5}$$

$$f_{\text{nrefC}} = 0.75 \cdot (n_{\text{hi}} - n_{\text{lo}}) + n_{\text{lo}} \quad \text{Eq. 1065.610-6}$$

*Example:*

$n_{\text{lo}} = 1005 \text{ rev/min}$   
 $n_{\text{hi}} = 2385 \text{ rev/min}$   
 $f_{\text{nrefA}} = 0.25 \cdot (2385 - 1005) + 1005$   
 $f_{\text{nrefB}} = 0.50 \cdot (2385 - 1005) + 1005$   
 $f_{\text{nrefC}} = 0.75 \cdot (2385 - 1005) + 1005$   
 $f_{\text{nrefA}} = 1350 \text{ rev/min}$   
 $f_{\text{nrefB}} = 1695 \text{ rev/min}$   
 $f_{\text{nrefC}} = 2040 \text{ rev/min}$

(3) *Intermediate speed.* If your normalized duty cycle specifies a speed as “intermediate speed,” use your torque-versus-speed curve to determine the speed at which maximum torque occurs. This is peak torque speed. Identify your reference intermediate speed as one of the following values:

- (i) Peak torque speed if it is between 60 and 75 % of maximum test speed.
- (ii) 60% of maximum test speed if peak torque speed is less than 60% of maximum test speed.
- (iii) 75% of maximum test speed if peak torque speed is greater than 75% of maximum test speed.

(d) *Generating reference torques from normalized duty-cycle torques.* Transform normalized torques to reference torques using your map of maximum torque versus speed.

(1) *Reference torque for variable-speed engines.* For a given speed point, multiply the corresponding % torque by the maximum torque at that speed, according to your map. Linearly interpolate mapped torque values to determine torque between mapped speeds. The result is the reference torque for each speed point.

(2) *Reference torque for constant-speed engines.* Multiply a % torque value by your maximum test torque. The result is the reference torque for each point. Note that if your constant-speed engine is subject to duty cycles that specify normalized speed commands, use the provisions of paragraph (d)(1) of

this section to transform your normalized torque values.

(3) *Permissible deviations for any engine.* If your engine does not operate below a certain minimum torque under normal in-use conditions, you may use a declared minimum torque as the reference value instead of any value denormalized to be less than the declared value. For example, if your engine is connected to an automatic transmission, it may have a minimum torque called curb idle transmission torque (CITT). In this case, at idle conditions (i.e., 0% speed, 0% torque), you may use CITT as a reference value instead of 0 N·m.

(e) *Generating reference power values from normalized duty cycle powers.* Transform normalized power values to reference speed and power values using your map of maximum power versus speed.

(1) First transform normalized speed values into reference speed values. For a given speed point, multiply the corresponding % power by the maximum test power defined in the standard-setting part. The result is the reference power for each speed point. You may calculate a corresponding reference torque for each point and command that reference torque instead of a reference power.

(2) If your engine does not operate below a certain power under normal in-use conditions, you may use a declared minimum power as the reference value instead of any value denormalized to be less than the declared value. For example, if your engine is directly connected to a propeller, it may have a minimum power called idle power. In this case, at idle conditions (i.e., 0%

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speed, 0% power), you may use a corresponding idle power as a reference power instead of 0 kW.

EFFECTIVE DATE NOTE: At 73 FR 37324, June 30, 2008, § 1065.610 was revised, effective July 7, 2008. For the convenience of the user, the revised text is set forth as follows:

### § 1065.610 Duty cycle generation.

This section describes how to generate duty cycles that are specific to your engine, based on the normalized duty cycles in the standard-setting part. During an emission test, use a duty cycle that is specific to your engine to command engine speed, torque, and power, as applicable, using an engine dynamometer and an engine operator demand. Paragraph (a) of this section describes how to "normalize" your engine's map to determine the maximum test speed and torque for your engine. The rest of this section describes how to use these values to "denormalize" the duty cycles in the standard-setting parts, which are all published on a normalized basis. Thus, the term "normalized" in paragraph (a) of this section refers to different values than it does in the rest of the section.

(a) *Maximum test speed,  $f_{ntest}$ .* This section generally applies to duty cycles for variable-speed engines. For constant-speed engines subject to duty cycles that specify normalized speed commands, use the no-load governed speed as the measured  $f_{ntest}$ . This is the highest engine speed where an engine outputs zero torque. For variable-speed engines, determine the measured  $f_{ntest}$  from the power-versus-speed map, generated according to § 1065.510, as follows:

(1) Based on the map, determine maximum power,  $P_{max}$ , and the speed at which maximum power occurred,  $f_{nPmax}$ . Divide every recorded power by  $P_{max}$  and divide every recorded speed by  $f_{nPmax}$ . The result is a normalized power-versus-speed map. Your measured  $f_{ntest}$  is the speed at which the sum of the squares of normalized speed and power is maximum, as follows:

$$f_{ntest} = f_{ni} \text{ at the maximum of } (f_{nnormi}^2 + P_{normi}^2)$$

Eq. 1065.610-1

Where:

$f_{ntest}$  = maximum test speed.

$i$  = an indexing variable that represents one recorded value of an engine map.

$f_{nnormi}$  = an engine speed normalized by dividing it by  $f_{nPmax}$ .

$P_{normi}$  = an engine power normalized by dividing it by  $P_{max}$ .

Example:

$$\begin{aligned} (f_{nnorm1} = 1.002, P_{norm1} = 0.978, f_{n1} = 2359.71) \\ (f_{nnorm2} = 1.004, P_{norm2} = 0.977, f_{n2} = 2364.42) \\ (f_{nnorm3} = 1.006, P_{norm3} = 0.974, f_{n3} = 2369.13) \\ (f_{nnorm12}^2 + P_{norm12}^2) = (1.002^2 + 0.978^2) = 1.960 \\ (f_{nnorm2}^2 + P_{norm2}^2) = (1.004^2 + 0.977^2) = 1.963 \end{aligned}$$

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$$\begin{aligned} (f_{nnorm3}^2 + P_{norm3}^2) &= (1.006^2 + 0.974^2) = 1.961 \\ \text{maximum} &= 1.963 \text{ at } i = 2 \\ f_{ntest} &= 2364.42 \text{ rev/min} \end{aligned}$$

(2) For variable-speed engines, transform normalized speeds to reference speeds according to paragraph (c) of this section by using the measured maximum test speed determined according to paragraph (a)(1) of this section—or use your declared maximum test speed, as allowed in § 1065.510.

(3) For constant-speed engines, transform normalized speeds to reference speeds according to paragraph (c) of this section by using the measured no-load governed speed—or use your declared maximum test speed, as allowed in § 1065.510.

(b) *Maximum test torque,  $T_{test}$ .* For constant-speed engines, determine the measured  $T_{test}$  from the power-versus-speed map, generated according to § 1065.510, as follows:

(1) Based on the map, determine maximum power,  $P_{max}$ , and the speed at which maximum power occurs,  $f_{nPmax}$ . Divide every recorded power by  $P_{max}$  and divide every recorded speed by  $f_{nPmax}$ . The result is a normalized power-versus-speed map. Your measured  $T_{test}$  is the torque at which the sum of the squares of normalized speed and power is maximum, as follows:

$$T_{test} = T_i \text{ at the maximum of } (f_{nnormi}^2 + P_{normi}^2)$$

Eq. 1065.610-2

Where:

$T_{test}$  = maximum test torque.

Example:

$$\begin{aligned} (f_{nnorm1} = 1.002, P_{norm1} = 0.978, T_1 = 722.62 \text{ N}\cdot\text{m}) \\ (f_{nnorm2} = 1.004, P_{norm2} = 0.977, T_2 = 720.44 \text{ N}\cdot\text{m}) \\ (f_{nnorm3} = 1.006, P_{norm3} = 0.974, T_3 = 716.80 \text{ N}\cdot\text{m}) \\ (f_{nnorm1}^2 + P_{norm1}^2) = (1.002^2 + 0.978^2) = 1.960 \\ (f_{nnorm12}^2 + P_{norm12}^2) = (1.004^2 + 0.977^2) = 1.963 \\ (f_{nnorm12}^2 + P_{norm12}^2) = (1.006^2 + 0.974^2) = 1.961 \\ \text{maximum} &= 1.963 \text{ at } i = 2 \\ T_{test} &= 720.44 \text{ N}\cdot\text{m} \end{aligned}$$

(2) Transform normalized torques to reference torques according to paragraph (d) of this section by using the measured maximum test torque determined according to paragraph (b)(1) of this section—or use your declared maximum test torque, as allowed in § 1065.510.

(c) *Generating reference speed values from normalized duty cycle speeds.* Transform normalized speed values to reference values as follows:

(1) *% speed.* If your normalized duty cycle specifies % speed values, use your warm idle speed and your maximum test speed to transform the duty cycle, as follows:

$$f_{nref} = \% \text{ speed} \cdot (f_{ntest} - f_{nidle}) + f_{nidle}$$

Eq. 1065.610-3

Example:

$$\begin{aligned} \% \text{ speed} &= 85\% \\ f_{ntest} &= 2364 \text{ rev/min} \\ f_{nidle} &= 650 \text{ rev/min} \end{aligned}$$